well set and thrifty, and but few fields were injured by lack of snow protection.—*T. F. Townsend.*

Porto Rico.—The rainfall was considerably below normal in most districts. Dry weather was favorable for the older canes, but detrimental to the newly planted. Sugar-making began in the south during the middle of the month; grade of juice below normal. In the north and east canes were not sufficiently matured for grinding. Sowing and transplanting of tobacco was active and general and the crop was doing well. October sowings were cut; yield average, with a good per cent of wrappers. Coffee picking continued in the highlands. Oranges abundant. Small crops scarce in places. Pastures and cattle in good condition.—*E. C. Thompson.*

South Carolina.—Although the mean temperature was below normal, there was little freezing weather, a condition favorable for the germination of wheat and oats, which attained good stands. The precipitation was excessive, which interfered with plowing and seeding. The weather conditions were favorable for winter truck in the coast truck regions, and it was in a promising stage of growth. Over the greater portion of the State the ground was thoroughly saturated, and streams had more than their normal flow of water.—*J. W. Bauer.*

South Dakota.—The month was warmer than usual, with very little precipitation. Live stock did well and was in good winter condition, but in some northern counties November snow remaining on the ground hindered grazing on the ranges part of the month and necessitated more than the usual feeding from stack. In some southern counties absence of snow covering part of the month was considered unfavorable for winter grains, though no special injury was apparent. The month closed with very little corn in the fields.—*S. W. Glenn.*

Tennessee.—The weather was generally favorable to winter grains. There was no serious damage from freezing. The rainfall was ample, being considerably more than the normal in the eastern section. At the end of the month wheat, oats, and rye were in good condition, with fine stands as a rule. Pastures were better than usual at this period. Fairly good progress was made in plowing and in other farm work of the season.—*H. C. Bate.*

Texas.—Cool weather prevailed during the greater part of the month. Killing frost occurred frequently over the interior and extended to the coast line on the 25th. Beneficial rains occurred during the month, putting the ground in good condition. Plowing, seeding, and cotton picking were somewhat delayed and unpicked cotton was considerably damaged. Small grains generally did well. Rice thrashing and cane grinding were completed, except in a few localities. Truck gardens were not doing well. Range and stock were in fair condition.—*E. E. Spencer.*

Utah.—Temperatures during the month were abnormally low. Precipitation, which was almost entirely in the form of snow, was deficient over the valleys, but above average in the mountains and more elevated portions of the section. Fall wheat was in very good condition and well protected by an ample covering of snow. Stock, though being fed in many localities, was thriving.—*R. J. Hyatt.*

Virginia.—The general weather conditions of the month were quite favorable for work in the field, as well as for the growth of winter crops. Wheat, oats, and clover did well, on the whole, while rye and barley advanced sufficiently to afford grazing for stock. Considerable plowing was done and much work in the way of gathering, housing, and husking corn was completed. Moderate cold spells caused some light freezing and thawing, but no damage resulted.—*Edward A. Evans.*

Washington.—The fore part of the month was unusually dry, except near the coast, but the last decade was wet, especially in the western section. There was snow at the end of the month throughout the eastern section. The weather was favorable for winter wheat, which was in good condition, although not so well advanced as usual when snow came and covered it at the end of the month.—*G. N. Salisbury.*

West Virginia.—On the whole the weather was exceptionally fine during the month. There were good rains and considerable freezing weather. Stock was in good condition and there was plenty of feed on hand. Early sown wheat was looking well, but late sown was somewhat injured, as there was practically no protection afforded by snow. Little farm work was done.—*E. C. Vose.*

Wisconsin.—The temperature during the month averaged considerably above the normal, although some stations in the northern section reported temperatures ranging from zero to 24° below during the second and third decades. The precipitation, which was a little below the normal, was fairly well distributed. It was generally in the form of snow, which afforded a fair protection to winter grains during the periods of severe cold. No weather conditions of an abnormal character were reported, and the general situation was satisfactory.—*H. B. Hersey.*

Wyoming.—The fall months were unusually favorable for the stock interests of the State, and the close of the year found stock in excellent condition; ranges still afforded good feed, and hay was plentiful. The supply of snow in the mountains was not up to the average for the season, but there was more than at the close of 1904.—*W. S. Palmer.*

SPECIAL ARTICLES.

DOCTOR MARGULES ON THE ENERGY OF STORMS.

By Dr. S. TETSU TAMURA. Dated Washington, December, 1905.

Dr. Max Margules, of Vienna, has enriched theoretical meteorology by an exceedingly suggestive and important memoir on "The energy of storms,"[1] published during 1905, as an appendix to the Yearbook of the Central Meteorological and Geodynamical Institute of Vienna, for the year 1903. The paper consists of two parts. The first part, which covers only four pages, is an excellent summary of his ideas on the energy of storms for the nonmathematical reader. The second part, which covers 22 pages, embodies the elegant mathematical analysis, by which he attained the ideas popularly expounded in the first part.

It may be easily seen that the kinetic energy of a kilogram of air moving with the speed of 30 meters per second is 450 units (kg. m^2 $sec.^{-2}$) and nearly equal to 0.1 calorie. This quantity, which is not large in comparison with the quantity of heat that a kilogram of air at the earth's surface receives and loses in one day, appears very large when the energy of a kilogram of air moving with the average velocity (say five meters per second) is taken as a unit of measure. It is not probable that a much larger part of the heat communicated to the air at the time of a storm is converted into kinetic energy. Hence there arises the important question, "What is that condition of the atmosphere in which a sufficiently large quantity of kinetic energy can be accumulated in order to produce a storm?"

The first task of Doctor Margules was to construct the *fundamental energy equations of a moving particle and a mass of air in a closed system.* From one of the equations of atmospheric motions relative to moving axes, Doctor Margules formed the following equation[2] of the kinetic energy of a unit mass of air,

$$\frac{d}{dt}\left(\frac{c^2}{2}+W\right)+\frac{1}{\mu}\left(\frac{dp}{dt}-\frac{\partial p}{\partial t}\right)-Rc\cos(R,c)=0. \qquad (1)$$

From this equation, together with the thermodynamic equation,

$$\frac{dQ}{dt}=c_p\frac{dT}{dt}-\frac{1}{\mu}\frac{dp}{dt} \qquad (2)$$

where dQ means an increase of the quantity of heat in a particle of air moving over the distance ds in the time dt, the following energy equation of a moving particle of air is obtained:

$$\frac{dQ}{dt}=c_p\frac{dT}{dt}+\frac{d}{dt}\left(\frac{c^2}{2}+W\right)-\frac{1}{\mu}\frac{\partial p}{\partial t}-Rc\cos(R,c) \qquad (3)$$

for the whole mass for a closed system.

The above equations must be integrated. The equation for kinetic energy thus obtained is

$$\frac{\partial}{\partial t}\int\left(\mu\frac{c^2}{2}+\mu W\right)dk+\int\frac{p}{\mu}\frac{d\mu}{dt}dk-\int Rc\cos(R,c)\,\mu dk=0. \qquad (4)$$

The thermic equation for the entire mass in the closed system becomes

$$\int\frac{dQ}{dt}\mu dk+c_v\frac{\partial}{\partial t}\int T\mu dk-\int\frac{p}{\mu}\frac{d\mu}{dt}dk. \qquad (5)$$

Finally the author obtained the energy equation of the air mass in the closed system as follows:

$$\int\frac{dQ}{dt}\mu dk=c_v\frac{\partial}{\partial t}\int T\mu dk+\frac{\partial}{\partial t}\int\left(\mu\frac{c^2}{2}+\mu W\right)dk-\int Rc\cos(Rc)\mu dk. \qquad (6)$$

[1] Ueber die Energie du Stürme.

[2] The notation is $W=$ the potential due to gravitation and the centrifugal force of the earth's rotation; c the velocity of the air; μ the density; p the pressure; R the resisting force of friction; T the absolute temperature; c_p the specific heat at constant pressure; c_v the specific heat at constant volume; k the volume of the closed system.

These general equations play an important rôle in the course of Doctor Margules's argument. The author adopts the following simplified notations:

$$K = \int \frac{\mu c^2}{2} dk = \text{kinetic energy of the whole mass of air;}$$

$$P = \int \mu W dk = \text{potential energy of position;}$$

$$I = c_v \int T \mu dk = \frac{c_v}{R} \int p dk = \text{internal energy.}$$

For an infinitesimal change of these quantities, δK, δP, δI are used. They are completely determined by their initial and final states. The following quantities depend upon the course of motion:

$$-\delta A = -\int dt \int \frac{p}{\mu} \frac{d\mu}{dt} dk = \text{work of the pressure in time } t;$$

$$-(R) = \int dt \int Rc \cos (Rc) \mu dk = \text{work of the force of friction;}$$

$$(Q) = \int dt \int \frac{dQ}{dt} \mu dk = \text{increase of heat.}$$

By means of these notations the author has thrown the equation of kinetic energy, the thermic equation, and the energy equation into the following simple forms:

$$\delta (K + P + A) + (R) = 0$$
$$(Q) = \delta I - \delta A$$
$$(Q) = \delta (K + P + I) + (R).$$

The motions of the atmosphere are conditioned by the importation of heat, but it may be possible that for certain great atmospheric motions the importation of heat is inappreciable. In such motions the initial and final states alone determine δA the work done by the pressure. It is also known that when the air mass is kept at constant temperature, or when every small particle of air mass behaves adiabatically, the quantity A takes the meaning of potential energy. The next condition is $(Q) = 0$, whence the author derives the energy equation as follows:

$$\delta K + (R) = -\delta (P + I).$$

With this equation Doctor Margules attempts, in the following chapters, to solve the problem of a closed system of dry air that without importation of heat can develop as much kinetic energy as we observe in storms. The mass of air in the closed system is supposed to possess a given temperature and pressure distribution and to be at rest in the beginning. It is put in motion and endeavors to establish a stable equilibrium. If there be no friction, the particles of air will oscillate and thus reach the position of equilibrium. If there be friction, a final state is reached in which kinetic energy is gradually consumed. Doctor Margules seeks for the greatest value of $\delta K + (R)$, which may be called the available kinetic energy of the system.

The author devotes the second chapter to the discussion of the simplest cases of the problem, namely: The application of the energy equation to the interchange of strata in an air column. As the first example, Doctor Margules calculates the available kinetic energy due to the change of the position of a stratum of air for two different conditions, that is to say, where there is a continuous temperature distribution and when there is a discontinuous temperature distribution. Then the author simplifies the condition of stable equilibrium by introducing the idea of entropy and of von Bezold's potential temperature, since equilibrium is stable, if the strata with higher potential temperature or with greater entropy lie above those of lower potential temperature or of smaller entropy. Next, the displacement of a particle of air that has a different temperature from that of the surrounding particles is incidentally considered. The rest of the chapter is given to the discussion of the fall of higher strata in an air column. In this case two strata of air lie initially one above the other in indifferent equilibrium, the entropy of the lower stratum being greater than that of the higher one. If the air mass is put in motion, then the strata will interchange their positions and Doctor Margules calculates the quantity of the available kinetic energy due to such an action.

In the third chapter the author gives an elaborate calculation of the kinetic energy of a mass of air which passes over adiabatically from a given initial state to a state of equilibrium. The problem first considered in this connection is the following: In the lower part of a closed system the two masses of air are at the beginning separated by a vertical wall, and the entropy of the air mass in the first section is smaller than that of the air mass in the second section. Now, what amount of kinetic energy becomes available when we remove the wall of separation and allow the two masses of air to pass adiabatically to the state of equilibrium? The problem is analogous to one already considered in the previous chapter. Next, Doctor Margules submits an approximate analysis of the case in which the two masses of air are respectively in stable equilibrium, but the entropy of a kilogram of the cold air of the higher layer is in the beginning smaller than that of the warm air of the ground layer. In the final state the whole mass of cold air spreads out below with the warm air above it. The rest of the chapter is devoted to the discussion of the available kinetic energy in the case of a continuous horizontal temperature distribution, when the vertical temperature distribution is such as to produce indifferent equilibrium. The chapter concludes with a comparison of these calculations with those for incompressible fluids.

Thus far Margules has paid attention to the consideration of the *dry air* only; but in the fourth chapter he enters on the discussion of the condensation of the moisture in a mass of air that changes its position, and of the influence of the heat of condensation upon the energy of a storm. It is evident that the energy equation

$$(Q) = \delta (K + P + I) + (R)$$

is applicable to a complex atmosphere of air, water, and vapor as well as to dry air. In this connection the author considers particularly the following two special cases: In chamber No. 1 the dry air is in indifferent equilibrium, and in chamber No. 2 separated from No. 1 by a vertical wall, the moist air, which is assumed here to possess the property of expanding only with an increase of heat but otherwise of behaving like dry air, and to be in indifferent equilibrium. After the removal of the partition between the chambers, the dry air in chamber No. 1 will spread itself out at the bottom with the moist air above it. The same results would be attained when stable equilibrium prevails initially in each chamber. To this case the energy equation may be applied in the form

$$\delta K + (R) = (Q) - \delta (P + I)$$

where Q is the heat added by the condensation due to expansion.

The air in chamber No. 2 cools by expansion less than the dry air in chamber No. 1. Therefore it affords only a small addition to $\delta (P + I)$. The difference between the two is exactly compensated by the flow of heat. Hence Margules concludes that the heat of condensation contributes nothing to the energy of the storm.

In his mathematical analysis and calculations the author has first made the following various assumptions: (1) that the mass of air forms a closed system, (2) that there is a sharp boundary between the cold and warm air, and (3) that there exist level surfaces of equal pressure. At first sight these assumptions appear to be too artificial, but they are made in order to solve the problem mathematically.

According to Doctor Margules, the kinetic energy of a mass of air is due to its internal energy and the work of gravity.

The potential energy of position is the source of the energy of the storm. It is shown in his analysis that a system in which the mass of air is brought down vertically from equilibrium can contain the required energy. Of the various kinds of storms, the *boeëns* that occur with a rapid rise of pressure and a rapid fall of temperature, and the tornadoes that, according to W. M. Davis, originate in the neighborhood of the boundary of cold and warm air masses, appear best to conform to the analysis and calculations of Doctor Margules.

The phenomena of atmospheric motion in the great storm fields which we call cyclones are less penetrating than in the *boeën*. These occur in the middle and high latitudes and appear to originate from the interaction of cold and warm air masses which lie horizontally contiguous. But afterwards in equilibrium the cold air spreads out in the lower strata. The author points out that it is not impossible that these great storms are created from the potential energy of a similar initial condition. Doctor Margules seems to disprove the condensation theory of storms advanced by Espy, Ferrel, and Oberbeck, but agrees with Professor Bigelow's idea that the cyclone does not originate from the energy of the latent heat of condensation, but that the energy of storms develops from the interchange of location of masses of air of unequal temperatures.

Doctor Margules' analysis and calculations, however, give only a general idea of the source of storm energy. A satisfactory model of the cyclone with asymmetrical distribution of temperature has not yet been constructed. Moreover, the peculiar conditions in the field of the tropical hurricane in which there does not usually occur any great temperature difference on the ground and where the cyclonic distribution of temperature reaches only to the height of a few kilometers, also need another investigation.

AIR AND WATER TEMPERATURES.

By W. F. COOPER, Michigan Geological Survey. Dated Lansing, Mich., December 16, 1905.

(1) LOWER MICHIGAN.

An examination of the yearly mean isothermal lines for lower Michigan, as given in the reports of the Michigan Section of the Climate and Crop Service of the U. S. Weather Bureau in cooperation with the Michigan State Weather Service, affords some suggestive comparisons. We have, for instance, prepared Table 1, showing the higher latitude of the annual isothermal lines on the west shore of lower Michigan as compared with the east shore for the years 1900–1904, inclusive.

TABLE 1.

Year.	Temperature.	Miles farther north on west shore of the lower peninsula.	Year	Temperature.	Miles farther north on west shore of the lower peninsula.
	° F.			° F.	
1900	48	10	1903	46	103
	46	20		44	66
1901	46	31	1904	44	54
	44	60		43	30
1902	48	1		42	42
	46	52		41	78
	44	60		40	40

From these data we see that the isotherm of 48° has been an average distance of 6 miles farther north on the west shore than on the east; that of 46°, 53 miles; of 44°, 60 miles; of 42° and 40° for the year 1904, 43 and 40 miles, respectively. An average of these combined data shows the same temperature averages extending 46 miles farther northward on the west side of the lower peninsula of Michigan.

As an exception to this general rule of higher isothermal lines on the western shore of lower Michigan, the isotherm of 48° for 1903 is eight miles farther north in Macomb County, adjacent to Lake St. Clair, than it is where Van Buren County is washed by the waters of Lake Michigan. Likewise during 1904 the line for 45° is sixteen miles farther south in Berrien County than in Macomb. Both these isothermals, however, show some deflection to the northward on approaching Lake Michigan.

(2) LAKE MICHIGAN.

Comparing the isothermals on the east and west sides of Lake Michigan, as given in the reports of the section directors of Michigan and Wisconsin, we obtain the following results:

TABLE 2.

Year.	Temperature.	Miles farther south on the east side.	Miles farther north on the east side.	Year.	Temperature.	Miles farther south on the east side.	Miles farther north on the east side.
	° F.				° F.		
1900	48	5	......	1902	46	......	50
	46	......	38	1903	46	......	100
	42	......	25		44	......	88
1901	48	23	......	1904	44	4	......
	46	......	16		42	......	33
1902	48	26	......				

Taking into account the negative figures in this comparison, the results show the average temperature on the east side of the lake 36 miles farther north than on the east coast of Wisconsin.

(3) SPECIAL OBSERVATIONS AND THEORY.

The object of this paper is to present some data showing the cause of this distribution of temperature. In obtaining the temperature observations thermometer No. 7529 by H. J. Green was used. The readings of the temperatures of the air over the land and of the water in the bay were taken on the west side of Saginaw Bay and east of Tobico Inlet, northwest of Bay City. Less than five minutes elapsed between the readings in the air over the land, and in the water. During August 12, 13, 15, 16, 17, and 18, 1904, the thermometer was read at 5:30 a. m. and hourly from 7:30 a. m. to 10:30 a. m., and 11:15 a. m., and hourly from 1:00 p. m. to 7:00 p. m., excepting at 6:00 p. m. August 22 and 23 readings were taken consecutively from 1:00 p. m. to 11:15 a. m. the following forenoon. August 25 and 26 the thermometer was read from 5:30 a. m. to 5:30 a. m., being consecutive for 24 hours ending August 26. The full record is given in Table 12. Judging from the last two series of observations the maximum and minimum temperatures were very nearly obtained by the readings taken from 5:30 a. m. to 7:00 p. m. These temperatures of air and water at Tobico will now be compared with the minimum and maximum readings taken by the cooperative observers of the Weather Bureau at Bay City, Midland, Saginaw (west side), and Hayes. Bay City is situated six miles southeast from Tobico, Midland sixteen miles west and somewhat south, Saginaw nineteen miles almost due south, Hayes thirty-six miles east-northeast across Saginaw Bay. These readings can be most conveniently presented in tables.

TABLE 3.—*Maximum and minimum temperatures, August 12, 1904.*

Location.	Maximum.	Minimum.	Range.
	°	°	°
Tobico, Saginaw Bay	73.5	68	5.5
Tobico, air	79	51	28
Bay City	80	48	32
Midland	80	58	22
Saginaw	80	48	32
Hayes	78	44	34